DELAMINATION MODELLING OF BIOLOGICAL SOFT TISSUES USING PUFEM

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The mechanics of biological soft tissues such as arteries, tendons, skin, ligaments, cartilage etc., is a multidisciplinary and rapidly expanding area of research. In particular, the design of efficient constitutive and numerical models for arterial walls is of pressing need to understand the interaction between wall structure and wall function, i.e. the underlying *biomechanics* and *mechanobiology*. The mechanical properties of arterial walls are basically governed by the complex three-dimensional network of structural proteins, i.e. elastin and collagen, and smooth muscle cells. In particular, the composition of the media of elastic arteries is dominated by these three components, which form a varying number of well-defined fiber-reinforced repeating lamellar units, each of which is about 10 mm thick [1].

There are several constitutive descriptions of arterial walls known in the literature that focus on the physiological loading range of arteries (a comparative study of a number of well-known constitutive models is given in [2]). Balloon dilation (the most frequently used therapeutical intervention worldwide for reducing the severity of atherosclerotic stenoses) often leads to tissue delamination (dissection) within the intimal and/or medial layer. After balloon deflation this results in tissue flaps with longitudinal orientations protruding into the vessel lumen [3].

In this communication we focus on the (physical and numerical) modelling of the delamination failure (dissection) of arterial walls caused by high non-physical loading. Embedded representations of localized failure are employed. They are suitable to capture cracking by combining the strong features of smeared and discrete approaches. Basically, in the kinematically framework a strong discontinuity (in terms of the Heaviside function) is incorporated, and a cohesive traction-separation law models the discrete constitutive response of the interface. From the numerical point of view, we follow the **P**artition of **U**nity **F**inite **E**lement **M**ethod (PUFEM) [4], and enrich the standard (polynomial) basis by the Heaviside function. The formulation is particularized for tetrahedral elements and the discontinuous part of the displacement field is represented by enhanced degrees of freedom at the element nodes [5]. A consistent linearization of the model – including the geometrical contributions of the traction terms – leads to a robust *and* efficient finite element formulation. The performance of the formulation is shown by means of a finite element analysis of the middle layer (the media) of an artery, which is considered to be delaminated (dissected). In addition, we aim to show the suitability of the model by comparing its predictions with experimental data of human arteries that are based on dissection tests performed in the authors' laboratory.

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References

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